



A11105 353034

REFERENCE

NIST
PUBLICATIONS

NIST

United States
Department of
CommerceTechnology
AdministrationNational Institute
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Technology

SPECIFICATIONS AND TOLERANCES

for Reference Standards

and Field Standard

Weights and Measures



4. Specifications and Tolerances for
Liquefied Petroleum Gas and Anhydrous Ammonia
Liquid Volumetric Provers

NIST
Handbook

105-4

1997

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NO. 105-4
1997

● Specifications and Tolerances for Reference Standards and Field Standard Weights and Measures

4. Specifications and Tolerances for Liquefied Petroleum Gas and Anhydrous Ammonia Liquid Volumetric Provers

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June 1997



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NIST
Handbook

105-4

1997

National Institute of Standards and Technology Handbook 105-4, 1997 Edition

Natl. Inst. Stand. Technol. Handb. 105-4, 1997 Ed., 23 pages (June 1997)

CODEN: NIHAE2

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON: 1997

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325

Preface

This 1997 version is the first publication of this handbook for LPG provers although several drafts have been in circulation for 5 years.

Note regarding units of measure:

The SI unit of volume is the cubic decimeter (dm^3) or the cubic centimeter (cm^3). The Twelfth General (International) Conference on Weights and Measures redefined the litre [herein spelled liter] as a "special name for the cubic decimeter," but agreed to permit the continuance of the terms liter (L) and milliliter (mL), except in association with measurements of the highest precision. The commercial measurement system in the United States continues to use gallons and cubic inches for practical applications. Since commercial applications in the United States use units other than SI or other accepted metric units, this document references other common units in current use. Specific applications in this handbook use units such as psig for which the SI unit is the Pascal; however, gages mounted on these provers use psig units. Also, manufacturers of these types of provers have indicated that some items such as piping are only available in inch sizes; therefore in those cases, available sizes are used.

Acknowledgment:

The first several drafts of this Handbook were written by James Clifford, metrologist with the State of Oregon. Special thanks regarding this edition is also given to Karl Herken, metrologist with the State of Kansas, for his assistance with review of reference materials, evaluation of comments submitted during peer review, and for typing and editing the document in WordPerfect format and for preparing draft diagrams. Special acknowledgment is given to Emil Hazarian, metrologist with Los Angeles County Weights and Measures, for preparing schematic diagrams. Thanks are also given to manufacturers and numerous metrologists (of both State and industry laboratories) for their technical review of several drafts.

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SPECIFICATIONS AND TOLERANCES FOR REFERENCE STANDARDS AND FIELD STANDARD WEIGHTS AND MEASURES

4. Specifications and Tolerances for Liquefied Petroleum Gas and Anhydrous Ammonia Liquid Volumetric Provers

These specifications and tolerances are recommended as minimum requirements for standards used by State and local weights and measures officials and others in the verification of meters used in the quantity determination of pressurized liquid commodities.

Key words: field standard provers; pressure vessels; provers; specifications; vapor return; volumetric standards; volumetric specifications and tolerances; weights and measures.

INTRODUCTION

Pressurized volumetric provers are used primarily to test commercial pressurized liquid measuring devices for compliance with commercial requirements. Use of these field standards at all appropriate levels of manufacture, distribution, and weights and measures inspection will help promote accuracy and uniformity in commerce. The breadth of topics in this handbook is intended to provide information for manufacturers, calibration staff, weights and measures officials, and other end users. References are provided when additional information may be useful to the reader.

1 Scope

1.1 "Field Standard" Classification

These specifications and tolerances are limited to pressurized, graduated neck type field standard provers. The field standards covered by this publication are intended to be used by weights and measures officials. Manufacturers and distributors of liquefied gases, service maintenance personnel, research and testing laboratories, and others concerned with volume measurements of pressurized

liquids may find these specifications and tolerances useful. Use of these standards at all appropriate levels of manufacture, distribution, and weights and measures inspection will help promote accuracy and uniformity in commerce.

The term "field standard prover" as used in this publication refers to all sizes in general. The provers referred to here are those whose volume is established between a graduated bottom zero and the nominal volume point on the graduated neck scale, when pressurized to 689.4757 kPa (100 pounds per square inch, gage, or "psig." The unit psig will be used hereafter.) In some cases, larger or special purpose standard provers may be required which are not specifically covered in this publication, for example, large provers mounted horizontally on a truck or trailer.

1.2 Retroactivity

These specifications are not intended to make obsolete those field standards which were fabricated according to prior specifications.

1.3 Safety Considerations

This standard involves hazardous materials, operations, and equipment. This standard does not purport to address safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Although these specifications include field standards for liquefied petroleum gas and/or anhydrous ammonia, these products cannot be interchanged in the use of the standard.

This handbook does not address possible emissions from field standards during their use in the testing of hydrocarbons or ammonia. Please note that venting propane within most city limits is usually prohibited and illegal.

Commercial pressurized volume measuring devices tested with these field standards, are typically used to measure quantities of petroleum products and other pressurized liquids. These liquids are known hazardous materials and hazardous wastes. The user is encouraged to obtain Material Safety Data Sheets (MSDS) from the manufacturer of any product encountered. Federal and local safety and disposal regulations concerning hazardous materials encountered should be reviewed by the user.

Field standards should be free of product prior to being submitted for test. For anhydrous ammonia measuring field standards, it is recommended that the interior be thoroughly flushed with water.

2 Reference Documents

Specifications in this handbook are based upon information contained in publications

from: National Fire Protection Association (NFPA), American Society for Testing and Materials (ASTM), American Society for Mechanical Engineers (ASME), Underwriters Laboratories (UL) and American Petroleum Institute (API).

2.1 OIML¹

2.1.1 First Draft, International Recommendation on Characteristics of Standard Capacity Measures and Test Methods for Measuring Systems, 1992.

2.2 NIST²

2.2.1 Handbook 44, Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices, see current edition, published annually.

2.2.2 Handbook 145, Handbook for the Quality Assurance of Metrological Measurements, 1986 or later edition.

2.3 API³

2.3.1 Manual of Petroleum Measurement Standards, Chapter 14.8.

2.4 ASTM⁴

2.4.1 D 1250, Standard Guide for Petroleum Measurement Tables.

2.4.2 Table 24, Volume Reduction to 60 °F.

2.4.3 Table 24B, Generalized Products, Correction of Volume to 60 °F Against Relative Density 60/60 °F.

2.4.4 Table 34, Reduction of Volume to 60 °F Against S.G. 60/60 °F for Light Petroleum Gases.

3 Terminology

Anhydrous Ammonia. A relatively pure form of ammonia, synthesized from nitrogen and hydrogen, combined at high temperatures and

pressures in the presence of a catalytic agent. Used primarily as a fertilizer, or a refrigerant. It will react rapidly with copper, brass, zinc and many alloys, especially those containing copper. Boils at atmospheric pressure at $-33.3\text{ }^{\circ}\text{C}$ ($-28\text{ }^{\circ}\text{F}$). Will contaminate LPG.

Cubical coefficient of thermal expansion. Three dimensional expansion or contraction of a material due to temperature change, expressed $^{\circ}\text{C}^{-1}$ or $^{\circ}\text{F}^{-1}$.

Excess Flow Valve (also called excess-flow check valve). A device designed to close when the liquid or vapor passing through it exceeds a prescribed flow rate as determined by pressure differential.

Hydrostatic Pressure Relief Valve. A pressure relief valve designed to protect piping between two shutoff valves from excessive pressure and possible rupture.

Liquefied Petroleum Gas (LPG). Means a mixture of normally gaseous hydrocarbons, predominantly propane, or butane, or both, that has been liquefied by compression, cooling, or both to facilitate storage, transportation, and handling.

Pressure Gage. A calibrated test capable of reading from 0 psig to 300 psig in 5 pounds per square inch increments (as applied to this specification).

Reflex Sight Gage. A liquid level gage, designed in such a way as to cause the liquid level to disrupt the refraction of light, causing the liquid within the gage to appear black.

Sight Flow Indicator. A fitting with windows, to visually observe flow through a pipe; may or may not be equipped with a mechanical flow indicator.

Standard. Physical realization or representation of a unit of measure. In the context of this handbook standard may mean a laboratory standard or a field standard.

Tolerance. Maximum permissible error. A value fixing the limit of allowable error or departure from the true performance or value.

4 Specifications

4.1 Physical Size

4.1.1 Size Declaration

The recommended sizes of field standard provers are represented by the nominal volume lines located on their scale plates. Recommended metric sizes are shown in Table 1, inch-pound sizes are shown in Table 2.

4.1.2 Size Limitations

Truck or trailer mounted provers must meet legal height requirements and width regulations. This will limit the maximum size of provers intended for portable operation. Pressure vessel design limitations along with practical and available calibration methods will limit the size of stationary provers.

4.2 Reference Temperature and Pressure

The following reference conditions shall be applied to the prover when calibrated to contain a volume equal to its nominal capacity: $15.56\text{ }^{\circ}\text{C}$ ($60\text{ }^{\circ}\text{F}$) and 100 psig. International standards reference petroleum products to $15\text{ }^{\circ}\text{C}$. Temperature and pressure measurements shall be accurate and traceable to national standards.

4.3 Material

4.3.1 Metal Construction Materials

A field standard should be constructed of low carbon steel or series 300 stainless steel. However, if used with anhydrous ammonia,

the standard shall be constructed of series 300 stainless steel. The vessel shall meet the requirements of Section VIII, Division 1 of the ASME Boiler and pressure vessel code. Brackets, fittings, handles and other associated hardware may be constructed of other materials, provided they are durable and are suitable for their intended purpose.

4.3.2 Intended Use Considerations

These specifications are not intended to preclude the use of other suitable materials, provided a standard made of such materials conforms to the applicable parts of these specifications. However, the material shall be of sufficient strength, shall be thermally stable, and not have an unduly high coefficient of thermal expansion which would render it unsuitable for field use. All applicable physical properties data must be accurately documented for the material chosen. Interested parties are urged to submit proposed designs to the Office of Weights and Measures, National Institute of Standards and Technology, Gaithersburg MD 20899 for evaluation before fabrication is begun.

4.4 Physical and Mechanical Properties

4.4.1 Body

Any cross section taken in a plane perpendicular to the vertical axis shall be circular, and the shape shall ensure complete emptying and draining. The volume of a prover shall be established without the use of fillers, adjusting plugs, or cavities of any kind.

4.4.2 Upper and Lower Necks

4.4.2.1 Design

The upper neck shall be seamless pipe, smooth inside and specially inspected and selected for uniformity in the circular cross section. Upper and lower necks shall be perpendicular to a level horizontal plane.

4.4.2.2 Safety collar

The top of the neck shall have a circular collar designed to protect the pressure relief valve from accidental damage and allow for complete drainage of water.

4.4.2.3 Upper sight gage

Field standards shall be equipped with a liquid level gage of the reflex type mounted as an integral part of the neck, or externally, provided that the fittings to the neck are equipped with excess flow valves. The sight gage shall be capable of displaying volume both above and below the nominal capacity graduation by an amount not less than 1.5 times the maintenance tolerance for the volume determined by the prover nominal capacity (or 1.5 percent of the prover volume), whether or not a device is equipped with an automatic temperature compensator.

NOTE 1: Available sight gages can display 2 to 2.5 times the maintenance tolerance above and below the nominal mark. This design extends the application of the prover for the user.

NOTE 2: Concerns have been raised regarding external gage tubes due to 1) the safety of external gage tubes with an increased number of fittings and 2) the potential for leaks and inaccuracy in measuring the volume due to thermal effects. One suggested advantage is improved accuracy and simplicity in reading the meniscus on external gage tubes.

4.4.2.4 Lower sight gage

A pressurized volumetric prover shall have a bottom zeroing capability (also called wet zero). The wet zero shall have a similar type liquid level gage as the top neck (but smaller) which is adequate for establishing a zero set-point.

4.4.2.5 Bottom valve

A bottom shut off valve must be positioned to allow setting of the prover "zero," and attached to a line carrying the liquid released to a port located above the upper neck of the prover. This port shall be equipped with a means of capping.

4.4.2.6 Drain plug

The lower neck shall be provided with a threaded plug to completely clean or drain the prover after calibration. The drain plug should not project above the bottom when inserted. The bottom should have a slight slope to facilitate drainage of prover through the drain plug.

4.4.3 Support Structure

The support structure of the prover, consisting of legs and framework shall be attached to reinforcement plates on the body of the prover. The attachment method of the support structure shall not contribute to prover deformation when routinely transported on a trailer or when fully loaded.

4.4.4 Pressure Vessel Compliance

The prover vessel shall comply with the "Rules for the Construction of Unfired Pressure Vessels," Section VIII, Division 1, ASME Boiler and Pressure Vessel Code. An LPG prover shall have a design pressure of 250 psig. A prover for use with anhydrous ammonia shall have a design pressure of 300 psig.

4.4.5 Thermometer Well

A thermometer well shall be installed on the main vessel of the prover and located so that the inserted thermometer can easily be read by the operator when reading the prover meniscus. The thermometer shall extend at least 8 inches into, and protrude 2 inches out of the prover at a downward angle of

approximately 15° from the horizontal plane and which will contain a temperature conducting liquid. The thermometer well should be located so that its lower (closed) end is at the approximate center of the vertical cross section of the prover. This thermometer well shall be sized to receive an armored glass, mercury thermometer and shall be provided with a removable cap connected to the prover body by a security chain. If dial face thermometers are installed to meet depth, location, and accuracy requirements, a well is not required.

For larger prover volumes than are identified in this handbook, more than one thermometer well should be spaced at two or three points in the upper, middle, and lower portions of the prover body.

SAFETY NOTE: Mercury thermometers (of any type) should not be used with anhydrous ammonia. Digital thermometers should be spark-free and explosion proof for either application.

4.4.6 Hardware

4.4.6.1 External piping requirements

Piping shall be ASME Schedule 80 and all fittings and valves shall comply with National Fire Protection Association (NFPA 58, Standard for the Storage and Handling of Liquefied Petroleum Gases, 1989). Provers intended for use with anhydrous ammonia shall have series 300 stainless steel valves, fittings, and piping throughout.

4.4.6.2 Pressure gage

Provers shall be equipped with a calibrated pressure gage piped to the vapor portion of the upper neck capable of reading 300 psig, with 5 pound per square inch graduations and mounted so that it is readable when the operator is reading the meniscus. This

pressure gage shall be equipped with an excess flow valve and a needle type shutoff valve between the gage and the pressure vessel.

4.4.6.3 Pressure valves

At the top of the upper neck, there shall be a pressure relief valve (set at 250 psig for LPG and 300 psig for anhydrous ammonia) to protect the vessel. All portions of the plumbing containing liquid, or capable of trapping this liquid, shall be equipped with an adequate hydrostatic relief valve. A static, positive displacement pump could be considered a hindrance for pressure equalization. All pipe attachments to the vessel shall be fitted with excess flow valves.

4.4.6.4 Vapor pressure equalization

Prover shall be equipped with a vapor return line (hose) at least 6 m (20 ft) in length with excess flow valve and shutoff valve at the prover end and appropriate shutoff valve with bleeder and connector for vapor fitting at outlet end.

4.4.6.5 Vapor return line

The vapor return line inside diameter shall be at least one-half the inside diameter of the liquid return line.

NOTE: Restrictive vapor return lines, or other system flow restrictions may contribute to proving errors.

4.4.7 Prover Leveling

A prover not permanently installed shall have adequate provisions for leveling. A truck or trailer mounted prover shall be equipped with a minimum of three, and preferably four, leveling jacks to safely maintain a level and stable condition when under full liquid load.

4.4.8 Scale Plate and Graduations

4.4.8.1 Material

The scale plate shall be rigid, and resistant to corrosion and discoloration (anodized aluminum or stainless steel).

4.4.8.2 Location

The scale plate shall be mounted on a secant directly in line with the edge of the reflex liquid level gage. The edge of the reading scale shall be not more than 3 mm (0.125 in) from the glass bezel.

4.4.8.3 Mounting

There shall be a sufficient number of scale brackets (minimum of two per scale plate) to hold the plate firmly. The scale plates shall be securely attached to the brackets and be provided with a means for sealing.

4.4.8.4 Scale units

The basic scale on metric standards shall be milliliters. The basic scale on inch-pound (customary) standards shall be decimal gallons (0.1 gal).

4.4.8.5 Mixed scale units

To avoid confusion and possible reading errors, dual scales on any one scale plate are not permitted; e.g., cubic inches and decimal gallons. Dual scales are permitted only when two scale plates are used. The basic scale shall be to the left of the liquid level gage when viewing the nominal volume line. If one of the scale plates is graduated in units other than milliliters or decimal gallons, it shall be placed to the right of the liquid level gage. If the two scale plates are graduated in the same measurement system; i.e., metric or inch-pounds, the nominal volume lines shall lie in the same horizontal plane. Where there may be graduations in different measurement units, the placement of the nominal volume

lines shall accurately reflect the relationship between the two systems, or each scale shall be capable of being adjusted and sealed separately.

4.4.8.6 Sealing and adjustment

All adjustments shall be provided with a means for sealing which will prevent movement or play. Removal or movement of the adjusting mechanism or scale plates shall not be possible without breaking the seal.

4.4.8.7 Incremental adjustment

Where the design of the scale adjustment provides for movement of the scale by increments only, the maximum increment shall be no larger than 25 percent of the smallest scale division.

4.4.8.8 Graduation spacing

The minimum distance between any adjacent graduation lines shall be 1.5 mm (0.0625 in) and the lines shall be evenly spaced.

4.4.8.9 Span of Graduations

The scales shall be graduated above and below the nominal capacity graduation by an amount not less than 1.5 times the maintenance tolerance (with or without temperature compensation) as determined by the prover nominal capacity. These tolerances are currently listed in NIST Handbook 44.

NOTE: If a sight gage is used that allows viewing of 2 to 2.5 times the maintenance tolerance, graduations should span the entire sight gage.

4.4.8.10 Scale lines

The graduation lines, numbers and other inscriptions on the scale plate shall be engraved or etched, permanent, and of a contrasting color to that of the plate.

4.4.8.11 Major divisions

Convenient major division lines, consistent with the measurement system used, shall be twice the length of the subdivision lines and shall be numbered to indicate the volume.

4.4.8.12 Lines spacing and width

The length of the major (numbered) graduation lines on scale plates shall be no less than 6 mm (0.25 in) and the minimum graduation lines shall be no less than 3 mm (0.125 in) in length. All lines shall extend to the edge of the scale plate nearest to the liquid level gage glass. Graduation lines shall be of uniform width and not more than 0.6 mm (0.025 in) or less than 0.4 mm (0.015 in) wide.

4.4.8.13 Nominal volume

The nominal volume line on all scale plates shall extend cross the entire width of the scale plate and shall be clearly identified.

4.4.8.14 Additional marking

Scale plates shall be clearly marked with the nominal volume of the prover and the intended method of use, such as contains or delivers.

4.5 Workmanship, Finish, and Appearance

4.5.1 Air Entrapment

Fabrication shall ensure that no pockets, dents, or crevices will be present which may entrap air or liquid, or impair the proper filling or draining of the standard. All drainage piping must be routed at a level lower than the bottom wet zero, especially in the area preceding valve(s). This will prevent an air pocket from forming when the prover is tested in the certifying laboratory.

4.5.2 Finished Quality

A field standard, together with its associated valves, piping, gage, etc., shall be free of slag, scale, weld or solder splatter, grit, dirt, dents, interior rust, water or product residue, or any other foreign matter before shipment from the factory or before submission for calibration.

4.5.3 Required Assemblies

All parts of the gage assemblies, and all piping and valves which affect the volume of a field standard, shall be fully assembled by the manufacturer or supplier.

4.5.4 Thread Connector Lubricant

All threaded connections, including plugs and caps, shall be thoroughly lubricated with a suitable nonhardening paste, or pipe joint tape, and shall not leak.

4.5.5 Valve Operation

All valves shall operate freely and positively and shall not leak under normal operating pressures.

NOTE: Valves are usually placed as close to the vessel as is practicable to limit the amount of measured product in the piping; however, operator accessibility may be a safety trade-off to valve location.

4.5.6 Leveling Jack Operation

All leveling jacks shall operate freely and be stable under load. Load rating should be determined on the basis of 125 percent of the anticipated maximum load including the heaviest product to be tested.

4.5.7 Metal Joints

All seams shall be filled and smooth to provide a continuous surface to prevent the entrapment of air or liquid, and shall not leak.

4.5.8 Internal Coatings

The interior surface of field standards made of low carbon steel shall be corrosion resistant or coated with a suitable material which will be impervious to the liquids for which the standard will be used.

4.5.9 Exterior Coatings

The exterior surface of field standards made of low carbon steel shall be properly primed and coated with a glossy finish (white) or a color which is reflective and prevents any unnecessary heating of the product within the prover.

4.5.10 Identification

4.5.10.1 Content

Each standard shall bear, in a conspicuous place the following information:

- 1) nominal capacity;
- 2) reference temperature for calibration;
- 3) name and address of manufacturer;
- 4) model number;
- 5) nonrepetitive serial or identification number;
- 6) material identification;
- 7) proof of ASME certification;
- 8) design working pressure;
- 9) date and pressure to which hydrostatically tested;
- 10) cubical coefficient of thermal expansion of material;
- 11) inside diameters of upper and lower necks; and
- 12) drain time after cessation of main flow or the total drain time.

4.5.10.2 Placement

Identification information shall be engraved or embossed on the standard or permanently placed on a metal plate which is permanently attached to the prover by the manufacturer without the use of adhesives.

4.6 Other Requirements

4.6.1 Levels

A prover shall be equipped with two non spring loaded, adjustable spirit levels, mounted at right angles to each other on the upper portion of the main vessel. Each level shall be mounted on a sturdy shelf and be equipped with a protective cover. The levels shall be adjustable to establish a reference to the upper neck of the prover in a vertical plane. The adjusting screws shall have provisions for sealing.

NOTE: Vehicle or trailer mounted provers may have auxiliary levels mounted at a lower plane for operator convenience in adjusting leveling jacks. If the pressurized prover is to be mounted with a nonpressurized prover it is recommended that all leveling be in reference to the pressurized prover. This is due to the much larger weight of pressurized provers and subsequent trailer flexure. Primary levels on the prover should be used to adjust auxiliary levels and as a reference; auxiliary levels are only to be used for coarse leveling.

4.6.2 Return Pump

The pump and piping shall be sized according to the prover volume and should be designed for use in LPG or anhydrous ammonia service. A return pump of a positive displacement type is generally recommended as most efficient for LPG.

4.6.3 Hoses

All hoses shall be at least 6 m (20 ft) in length and marked by the manufacturer with working and burst pressure ratings, designated for the intended use, and include the date of manufacture.

4.6.4 Protective Caps

The ends of all fill, product return, and vapor equalizing lines or hoses on a truck or trailer

mounted prover shall be supplied with removable caps or mounted male fittings of like size to secure and cap hoses when not in use.

4.6.5 Electrical Requirements

4.6.5.1 Grounding

A grounding lug is required on provers used for flammable materials to protect against accidental discharge of electricity. The lug shall be mounted on the base of the prover and in a position adjacent to the point where the prover is loaded.

4.6.5.2 Wiring

All electrical connections must be explosion proof. All wiring, including low voltage wiring shall meet the requirements of Article 300, 500, Group D, Class 1, Division 1, and 250.45 and/or other applicable articles of the latest edition of the National Electrical Code.

4.6.6 Braking System

The truck or trailer mounted prover shall have an adequate braking system to handle the load.

5 Tolerances (Maximum Permissible Errors)

5.1 Capacity Tolerances

The tolerances in Table 1 and 2 are the maximum allowed if the standard is to be used without correction in meter testing applications. Provers should be adjusted during calibration to nominal values if at all possible. Tolerances are based on an evaluation of the expanded uncertainty of the calibration and one third of the current acceptance tolerance (from NIST Handbook 44 tolerance tables to be applied to the device being tested.)

5.2 Neck Calibration Tolerance

The maximum capacity tolerance between the nominal volume line and any other line on the

scale shall be less than 0.5 percent of the total graduated neck volume.

6 Verification Requirements

6.1 Legal Requirements

The specifications and tolerances specified in Tables 1 and 2 are intended to permit the use of the equipment in normal field testing operations as standards having nominal values. Weights and measures requirements, including but not limited to, inspection, testing, and sealing by a NIST recognized laboratory, shall be followed.

NOTE: Some States have requirements not documented here.

6.2 Traceability

Field standards used for legal metrology shall be traceable to national standards by calibration in a laboratory recognized to calibrate in that parameter, range, and scope.

6.3 Calibration Reports

Acceptable accuracy and traceability to national or international standards shall be documented in a calibration report using accepted test methods. A calibration report must be prepared that states the calibration method used, the calibration medium (should be water), the nominal volume of the prover, the reference temperature, the reference pressure, the volumes at various applied pressures, the calibration error on the graduated neck, the expanded uncertainty ($k=2$), the prover serial number, and the date. A pressure correction table and a temperature correction table should be provided with the calibration report.

6.4 Initial and Periodic Verification

Field standards must be verified prior to use and rechecked as often as regulations or circumstances require, especially when

damage is known or suspected. LPG prover calibration may be established at 1 year intervals and extended or reduced based on historical evidence up to the limit determined by State or local regulations, but should not exceed 3 years due to possible leaking valves or seals which are often difficult to observe under field conditions.

7 Test Methods and References

7.1 NBS Handbook 145, SOP 21

SOP 21, Recommended Standard Operating Procedure for Calibration of LPG Provers.

Test methods shall comply with those documented in NBS Handbook 145 or other nationally or international recognized procedure.

8 Uncertainties

8.1 Legal Applications

Uncertainties of the calibration must be evaluated according to the ISO Guide to the Expression of Uncertainty in Measurements,⁵ 1993 to ensure that the three to one accuracy ratio of NIST Handbook 44 is maintained. As of 1996, the acceptance tolerance for liquid petroleum gas and anhydrous ammonia measuring devices is 0.6 percent of the measured volume. Therefore, the expanded uncertainty for calibration of an LPG prover must be less than 0.2 percent of the measured volume.

8.2 Sources of Variation

8.2.1 Accuracy

Accurate measurement demands the use of calibration equipment and standards with accuracy traceable to national or international standards and the use of standard procedures. Accurate and traceable measurements require the analysis of measurement uncertainty and an evaluation of that uncertainty to determine the adequacy for its intended use. In the case

of LPG and anhydrous ammonia provers used in weights and measures applications, the expanded uncertainty for calibration must be less than 0.2 percent of the measured volume.

To achieve the required expanded uncertainty, the following estimates demonstrate the required standard uncertainties associated with major contributors in the calibration:

- laboratory standard(s): 0.01 percent of the volume of the prover under test;
- measurement process: 0.02 percent of the volume of the prover under test;
- neck calibration: 0.5 percent of the neck volume (the neck volume is at least 3 percent of total volume) of the prover under test; and
- applicable tolerance: 0.05 percent of the nominal volume for the prover under test.

When these factors are combined in a root-sum-square method and multiplied by a k-factor of two (95 percent confidence interval), it provides an uncertainty of less than 0.2 percent of the measured volume. If any one of the factors listed is greater than what is noted in the above list, the other factors must be reduced to compensate when one desires to maintain the required values for the expanded uncertainty.

E.g., for the previous example, the values are combined as follows:

$$U = 2 * \sqrt{0.01^2 + 0.02^2 + (0.5 * 0.03)^2 + 0.05^2}$$

To achieve the necessary accuracy, the corrected volume depends on:

- use of proper temperature corrections;
- the uncertainty associated with the cubical coefficient of thermal expansion;

- the accuracy of temperature measurements;
- correction for the compressibility of water; and
- use of an accurate pressure gage.

A single standard (as few as possible) should be used in the calibration of an LPG prover. Standards must have a valid calibration report with a sufficiently small expanded uncertainty.

Through proper use of documented laboratory and field procedures, additional uncertainty factors may be minimized to a level that does not contribute significantly to the previously described factors. Additional standard uncertainties in the calibration of LPG provers and their use in meter verification may include:

- how the prover level is established;
- how delivery and drain times are determined;
- the use of a proper "wet down" prior to calibration or use;
- whether gravity drain is used during calibration or whether the volume of water is eliminated by pumping;
- differences in drain between calibration and use;
- wetting characteristic differences between water and LPG or anhydrous ammonia;
- the cleanliness of the prover and calibration medium;
- prover retention characteristics related to inside surface, contamination or corrosion, and total drain times;
- possible air entrapment in the water; and
- the ability to properly read the meniscus.

Proper reading of the meniscus should be followed to prevent additional error in the

calibration and use (see NIST Handbook 145, Good Measurement Practice 3).

If the same pressure gage is used during calibration *and* during meter verification, errors due to inaccuracy should be minimized.

8.2.2 Repeatability

The LPG prover must be capable of repeating to 0.02 percent of the test volume during calibration. Repeatability problems may be the direct result of a leak in the valves or seals of the prover, or due to contamination and lack of cleanliness, and must be corrected before calibration can be completed.

Notes

1. OIML, L'Organisation Internationale Métrologie Légale, Bureau International De Metrologie Legale, 11, Rue Turgot, 75009, Paris, France.
2. NIST, National Institute of Standards and Technology, Gaithersburg, MD 20899.
3. API, 1220 L St. NW, Washington, DC 20005.
4. ASTM, American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.
5. ISO, International Organization for Standardization, Geneva, Switzerland.

Table 1. Metric specifications and tolerances for LPG provers

Size Liters (L)	Tolerance (mL)	Graduations (mL)	Neck Volume on Scale (L)	Maximum Upper Neck ID*** (in)	Lower Neck Diameter (in)
100	100	50	4	5	4
200	200	100	8	6	4
500	400	200	20	10/12	4
1 000	800	200	40	12	4

Table 2. Customary specifications and tolerances for LPG provers

Size (gal)	Tolerance*		Maximum Graduations (gal)	Neck Volume on Scale (gal)	Maximum Upper Neck ID (in)	Lower Neck Diameter (in)
	(in ³)	(gal)				
20	2	0.01	0.01	0.8	5/6	4
50	5	0.02	0.02	2	8	4
100	10	0.05	0.05	4	12	4
200	20	0.10	0.1	8	18	4

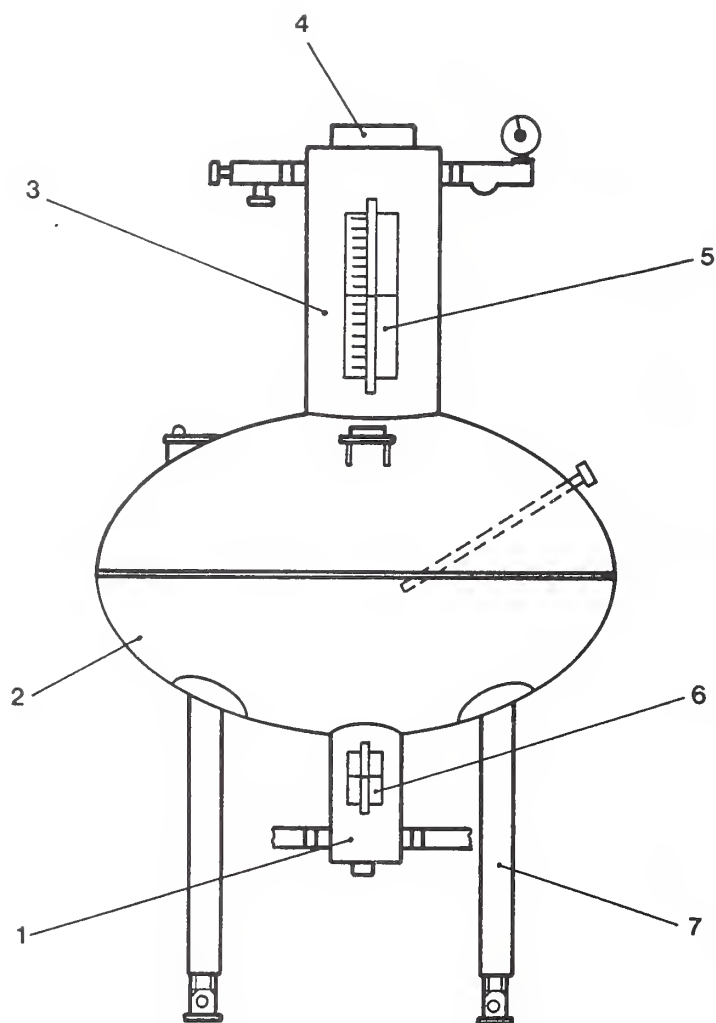
ID = inside diameter.

*Units are often rounded to the nearest appropriate unit and are not exact conversions between units.

**Neck volume figures are based on determining the error within 1.5 times the total maintenance tolerance for listed nominal values. If increased readability of range or increased sensitivity is desired, length of reading scale may be adjusted with proportional adjustment of neck diameter, provided height constraints are not exceeded.

***Neck diameter may vary; the critical factors to be considered which affect neck diameter are the volume above and below zero, the graduation sizes, and the minimum space between graduations.

For a capacity intermediate between two capacities listed above, the tolerances prescribed for the lower capacity shall be applied.



- 1 Lower Neck
- 2 Prover Body
- 3 Upper Neck
- 4 Collar
- 5 Reflex Gauge and Scale Assembly (Top)
- 6 Reflex Gauge and Scale Assembly (Bottom)
- 7 Leg

Figure 1. Schematic drawing of the LPG and anhydrous ammonia prover.

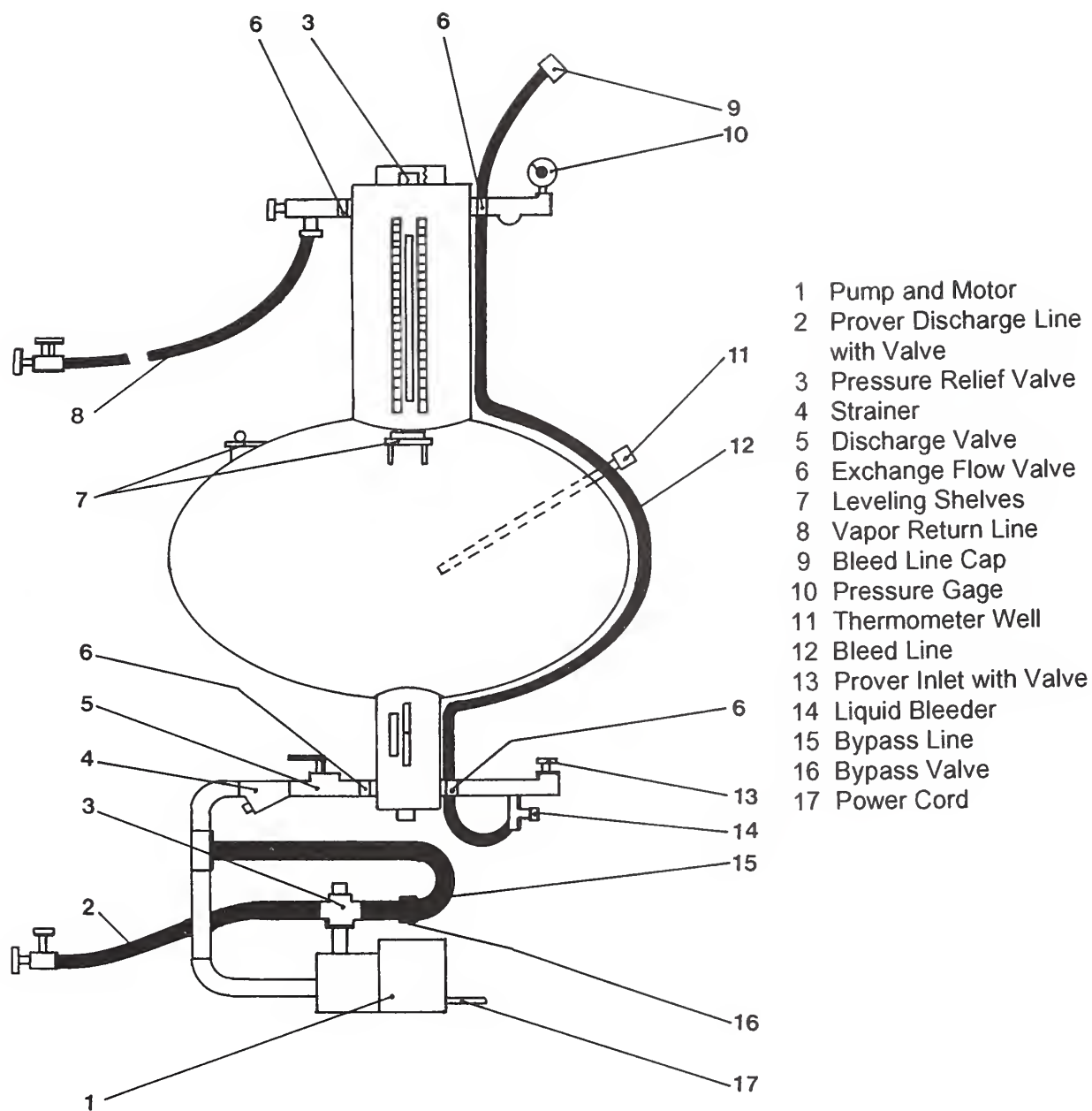
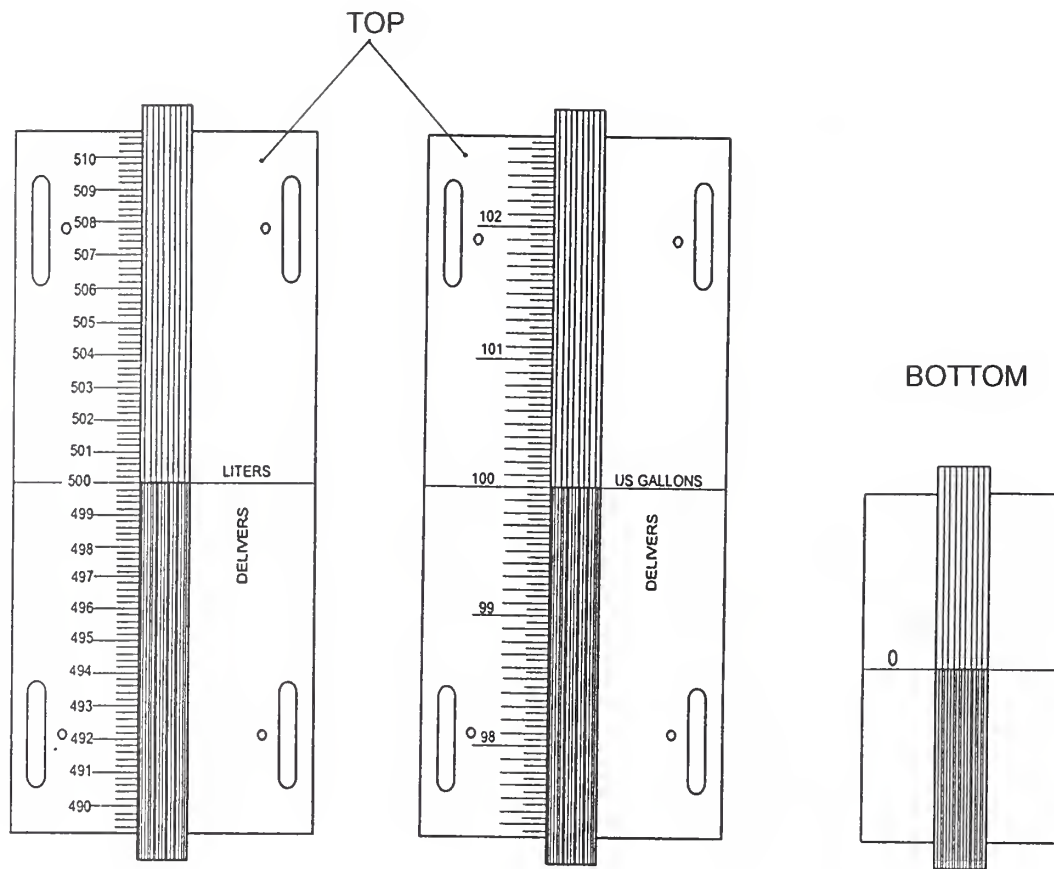


Figure 2. Schematic drawing of the hardware/plumbing.



SEALING DETAILS

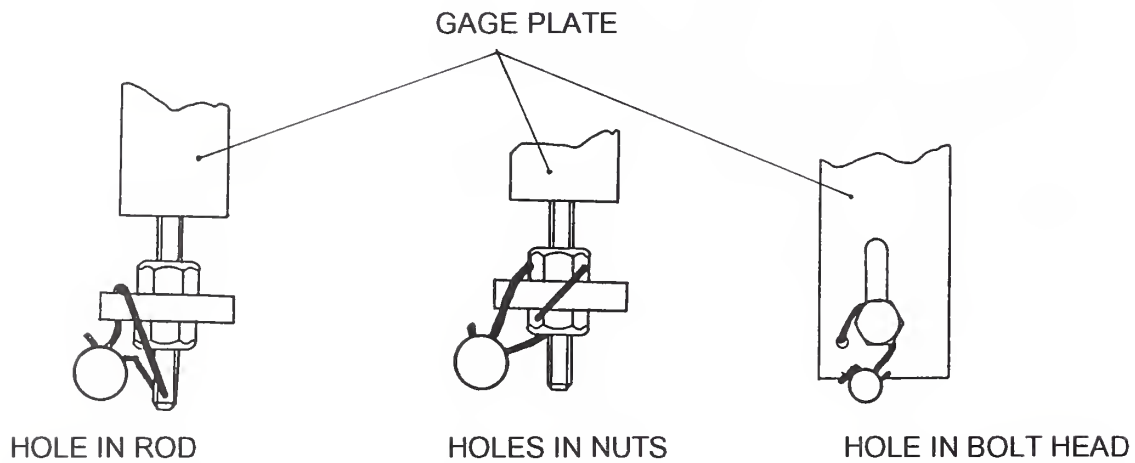
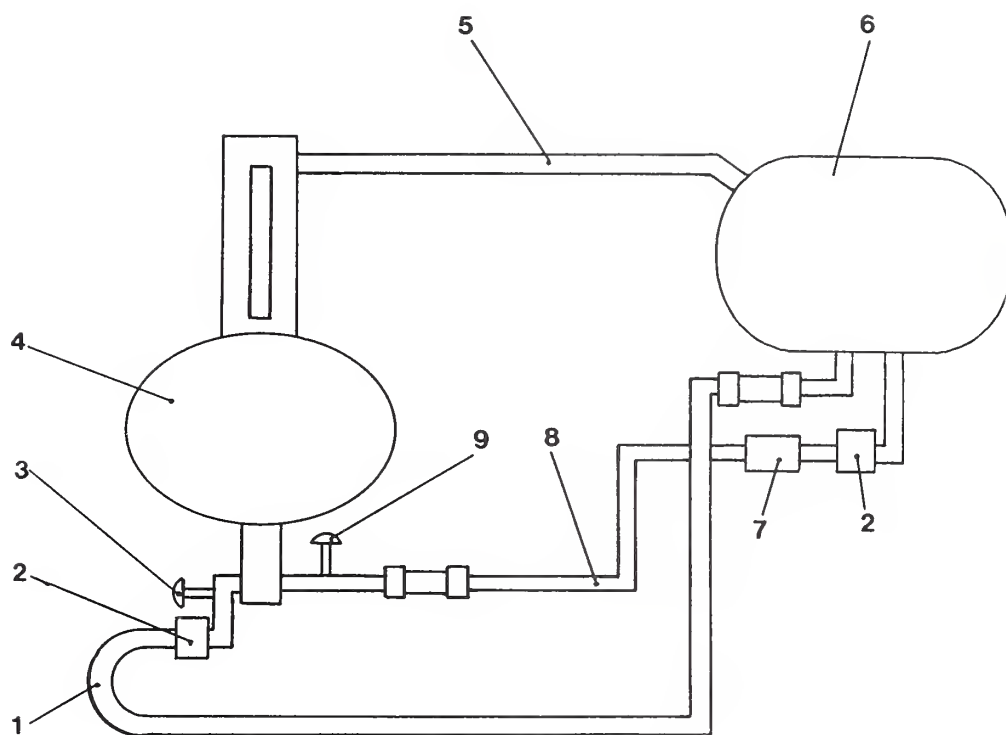


Figure 3. Schematic drawing of gage plates (top and bottom).



- 1 Liquid Return Line
- 2 Pump
- 3 Prover Outlet Valve
- 4 Prover
- 5 Vapor Return Line
- 6 Storage Tank
- 7 Metering Unit
- 8 System Discharge Line
- 9 Prover Inlet Valve

Figure 4. Schematic for use of prover in meter verification.

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